69-85

HEAT-STERILIZABLE, REMOTELY ACTIVATED BATTERY DEVELOPMENT PROGRAM

PHASE I

Third Quarterly Report

Period: January 1 to March 31, 1969

Contract No. 952214
NAS7-100

April 25, 1969

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91103

N69-35628

ELECTRONICS DIVISION
Eagle-Picher Industries, Inc.
Couples Department
Joplin, Missouri

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"This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, as sponsored by the National Aeronautics and Space Administration under Contract NAS7-100."

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"This report contains information prepared by Eagle-Picher Industries, Inc., under JPL Sub-Contract. Its content is not necessarily endorsed by The Jet Propulsion Laboratory, California Institute of Technology, or The National Aeronautics and Space Administration."

ABSTRACT

This report delineates the progress during the third quarter of the development of a heat sterilizable, sealed, remotely activated battery per contract number 952214 between The Jet Propulsion Laboratory and Eagle-Picher Industries, Inc. The work is moving toward the completion of Phase I, defined as an investigation of basic cell and battery components.

Studies pertaining to the silver oxide plate have shown that a single 120 hour sterilization cycle at 135°C will result in a 30%-40% reduction in capacity. Two cycles extend the reduction in capacity by approximately 4%. The plates tend to become stable with respect to weight loss and physical growth after the first 60 hours of 135°C storage. When subjected to the combination of vacuum and temperature necessary to eliminate any residual solvent in the polysulfone seals, the silver oxide plate lost an average of 2.5% in weight and increased in size similar to plates which had been sterilized. Plates which had been stored at least 60 hours at 135°C were not affected by the vacuum-temperature combination. Tests have shown that during a sterilization cycle an 8.0 gram plate with 12% oxygen will release approximately 400 cc of gas. A second cycle results in 17 cc of gas per plate.

The negative (zinc) electrode lost approximately 18% capacity without any change in size due to sterilization at 135°C for 120 hours. The vacuum-temperature combination had no effect on the plates.

An effective method of eliminating solvent (methylene chloride) from the polysulfone joints has been developed. This involves a 72-hour storage in an atmosphere of 300 microns or less with a chamber temperature of 85°C.

Polysulfone has been proven capable of dry sterilization. Resistance without crazing to boiling potassium hydroxide has also been shown.

The specific gravity of potassium hydroxide solution has been found to reduce the cell plateau voltage of silver oxide-zinc cells by the quantity .03 times the specific gravity. Sterilization of the electrolyte causes a reduction in the open circuit voltage. Neither specific gravity nor sterilization of the electrolyte affects the cell capacity.

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1.0 INTRODUCTION

This report presents the results of work during the third quarter ending 31 March 1969. The individual components necessary for a remotely activated heat-sterilized battery were studied.

2.0 TECHNICAL DISCUSSION

2.1 Silver Oxide Electrode

During the past quarter a series of tests were performed to determine certain characteristics of the electroformed silver oxide plate. These tests determined the stability of plates during 135°C sterilization and at reduced pressures with elevated temperatures. Discharge tests were conducted to define the electrical characteristics of the plates after each environment.

Each cell discharge utilized two negative and one positive plates separated by a single layer of 2409 cotton as manufactured by Kendall Mills. A rate of 4.0 amperes to an end voltage of 1.0 volts was used. All cells were vacuum activated with a 1.30 specific gravity solution of potassium hydroxide. Each plate was die cut to dimensions of 1.62 inches wide by 2.00 inches high.

The first series of tests were actually a continuation of the tests reported in the second quarterly report. Fourteen unsterilized plates were fabricated into cells and discharged. These plates represented the "before sterilization" version of the data shown in Table II of the second quarterly report. Based on a comparison of the data from the unsterilized plates as shown in Table I with that of the sterilized plates in the second quarterly report, the average capacity loss was approximately 40%. The correlation between plate density and capacity indicates that higher densities result in lower capacities and lower densities with higher capacities for plates of the same

TABLE I

CHARACTERISTICS OF UNSTERILIZED

SILVER OXIDE PLATES

Plate No.	Original Weight (gms)	Original Thickness (in.)	Original Density (gm/in^3)	Plateau Voltage (volts)	Open Circuit Voltage (volts)	Capacity (Amp-Min.)
17	8.25	.030	84.62	1.37	1.82	152
20	8.54	.032	82.12	1.37	1.79	156
25	7.76	.026	91.83	1.37	1.83	138
58	8.24	.025	101.42	1.38	1.82	138
71	8.05	.025	99.08	1.38	1.82	132
116	9.17	.025	112.86	1.33	1.83	130
136	8.54	.025	105.11	1.37	1.84	132
169	10.02	.033	93.43	1.32	1.84	184
192	9.44	.034	85.43	1.36	1.78	176
209	9.17	.033	85.50	1.33	1.86	164
247	9.39	.029	99.63	1.38	1.84	148
260	10.00	.029	106.10	1.38	1.86	180
309	8.05	.030	82.56	1.37	1.79	142
315	7.76	.030	79.59	1.31	1.74	108

2.1 <u>Silver Oxide Electrode (Continued)</u>

weight. The statistical analysis reported in the second quarterly report gave similar results.

As indicated in the second quarterly report, the elimination of plate growth and gassing from the silver oxide plate is desirable. Fourteen plates were selected for a study to ascertain the stability of the silver oxide plate after sterilization. After the plates were measured and weighed, seven were subjected to sterilization at 135°C for 120 hours. At the end of the sterilization cycle the individual weights and dimensions were determined. The plates were then subjected to a second 135°C sterilization. Losses in weight and dimensional changes were determined for each cycle. These data may be seen in Table II. As can be determined from the table, the second sterilization cycle caused no further significant growth.

The fourteen plates were then made into cells and discharged. The data are tabulated in Table III. The average loss in capacity was 42%. Based on the data in Table II pertaining to weight loss, approximately 4% of the 42% capacity loss was caused by the second sterilization cycle. All voltages of the plates subjected to two 135°C cycles were characteristic of monovalent plates.

As a supplement to the above test, eight silver oxide plates were subjected to 128 hours at 135°C. The plates were sealed in a tin container with connections made to measure gas outside the oven. Readings were taken at time intervals in order to determine the rate of gassing. Gas was collected during two 128-hour cycles with the amount of weight loss and dimensional changes of the plates determined before and after each cycle. After the final sterilization the plates were discharged in cells as described earlier. The rate of gas collected for the two cycles is shown in Figure I and II. As shown, 90% of

TABLE II

EFFECT OF STERILIZATION CYCLES

On

SILVER OXIDE ELECTRODES

Plate No.	% Loss in Weight			% Increase in Thickness			% Increase in Height			% Increase in Width		
	1st Cycle	2nd Cycle	1 & 2 Cycle	1st Cycle	2nd Cycle	1 & 2 Cycle	1st Cycle	2nd Cycle	1 & 2 Cycle	1st Cycle	2nd Cycle	1 & 2 Cycle
38	3.953	0.427	4.364	8.461	-0.709	7.692	3.999	0.048	4.049	8.430	0.283	8.739
57	4.209	0.064	4.271	10.416	0.000	10.416	4.349	0.095	4.449	8.061	-0.056	7.999
326	4.705	0.831	5.498	0.645	0.961	1.612	3.999	-0.048	3.950	9.046	-0.112	8.923
177	4.325	0.704	4.999	6.875	0.877	7.812	4.849	-0.333	4.499	8.799	0.113	8.923
296	5.025	0.522	5.521	10.370	0.671	11.111	3.950	0.048	3.999	9.661	-0.112	9.538
241	4.428	0.379	4.791	8.214	-0.990	7.142	4.749	-0.238	4.499	7.692	0.000	7.692
255	4.493	0.386	4.862	10.714	0.000	10.714	4.749	0.095	4.849	7.323	0.057	7.384

TABLE III

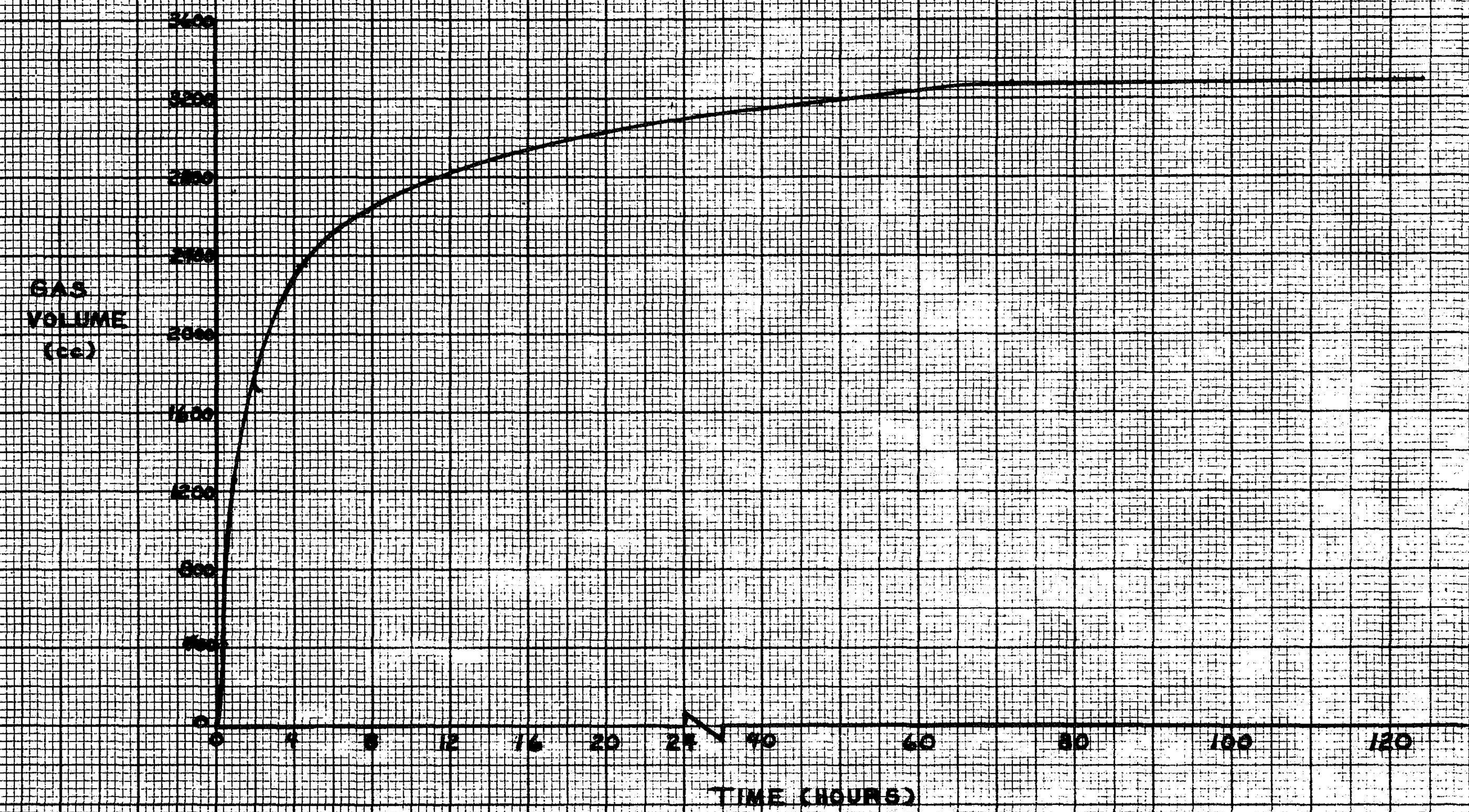
EFFECTS OF TWO STERILIZATION CYCLES

On

SILVER OXIDE PLATES

Plate No.	Original Weight (gms)	Original Thickness (In.)	Original Density (gms/in^3)	Plateau Voltage (Volts)	Open Circuit Voltage (Volts)	Capacity (Amp-Min)	Remarks
38	7.79	.026	92.19	1.23	1.57	84	Sterilized
57	8.10	.024	103.85	1.30	1.60	84	Sterilized
326	8.33	.031	82.68	1.29	1.58	78	Sterilized
177	8.90	.032	85.58	1.24	1.58	84	Sterilized
296	7.86	.027	89.57	1.23	1.62	72	Sterilized
241	9.10	.028	100.00	1.27	1.59	88	Sterilized
255	9.48	.028	104.18	1.30	1.62	94	Sterilized
48	7.79	.026	92.19	1.33	1.85	140	Unsterilized
297	7.85	.027	89.46	1.34	1.85	140	Unsterilized
60	8.10	.025	99.69	1.36	1.85	148	Unsterilized
316	8.33	.030	85.44	1.34	1.77	162	Unsterilized
188	8.90	.032	85.58	1.28	1.85	128	Unsterilized
248	9.10	.029	96.55	1.30	1.87	144	Unsterilized
251	9.48	.028	104.18	1.33	1.90	148	Unsterilized

FIGURE I
GASSING OF SILVER-OXIDE PLATES
DURING
HEAT STERILIZATION
(8 PLATES)
INITIAL CYCLE @ 135°C



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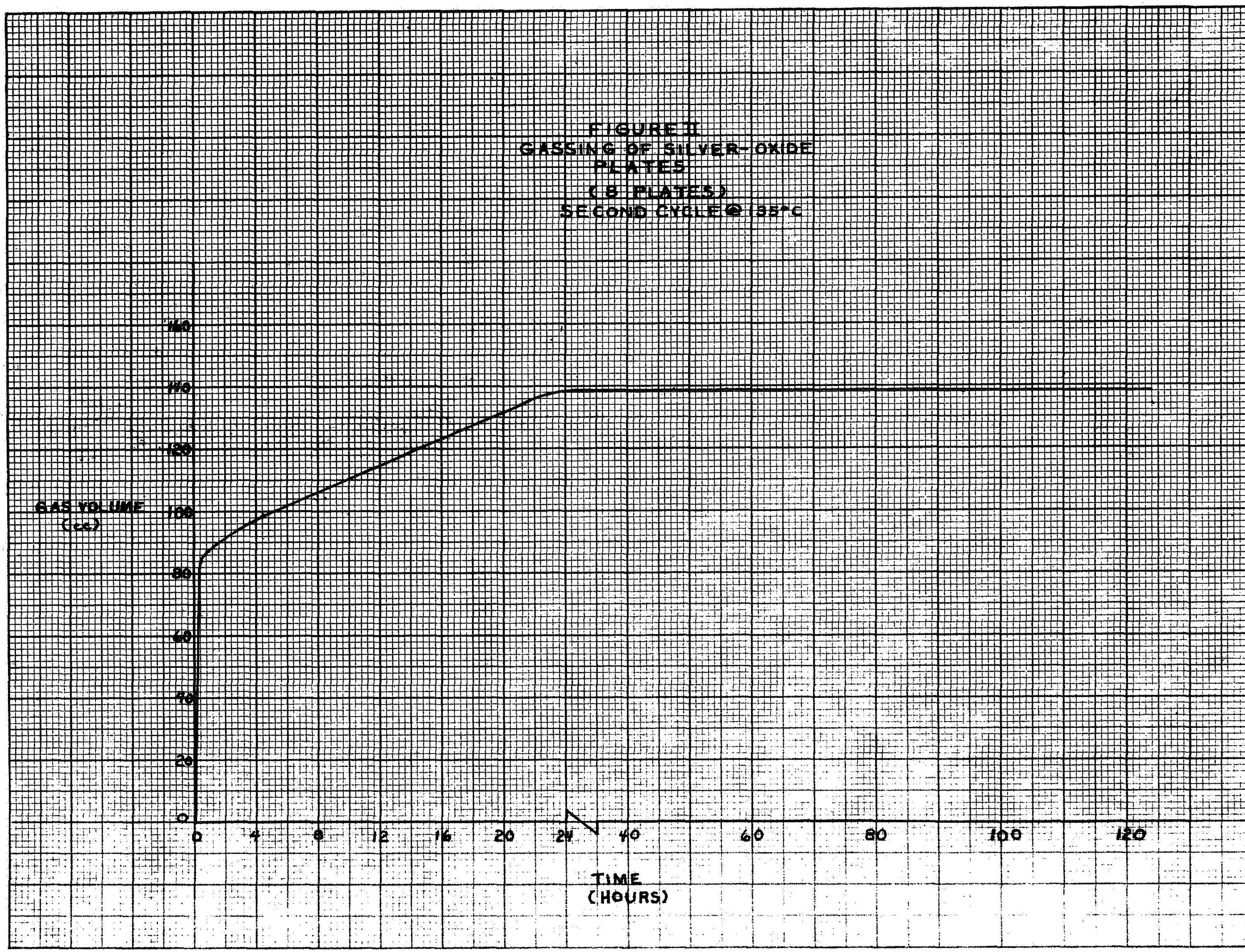


FIGURE II
GASSING OF SILVER-OXIDE PLATES
(8 PLATES)
SECOND CYCLE @ 135°C

2.1 Silver Oxide Electrode (Continued)

the gas emitted during the first cycle was collected within the first 24 hours. The plates evidently reached a near stable point after 60 hours.

In order to estimate the potential gas evolution of the plates over a longer storage time at 135°C, the quantity of gas collected was plotted against the reciprocal of time. This is shown in Figures III-a & b. The curve indicated a maximum gas emission of 3300 cc during the initial sterilization cycle.

Figure III-b shows a definite point of stability after 20 hours of the second cycle.

Considering the results of the stability and gassing studies, the problem posed may be avoided by heat treating the plates prior to sizing at 135°C for at least 60 hours. The plates may then be cut to size and separated into cells without any further expectation of appreciable dimensional growth or gassing.

While determining the best method of sealing polysulfone cell cases, the question arose as to the effect the solvent and the reduced pressure at 85°C needed to remove the solvent from the seals has on the silver oxide plates. A study was set up to subject two silver oxide plates to the thermal vacuum for 72 hours. The results of the test indicated an average weight loss per plate of 2.5% with dimensional changes slightly below that of plates subjected to 135°C heat sterilization. The data are tabulated in Table IV.

A second test was conducted using six plates which had been sterilized 128 hours at 135°C. Data from these plates show no changes during the 72-hour storage at 85°C with a pressure of 100 microns. This test was made with polysulfone seals,

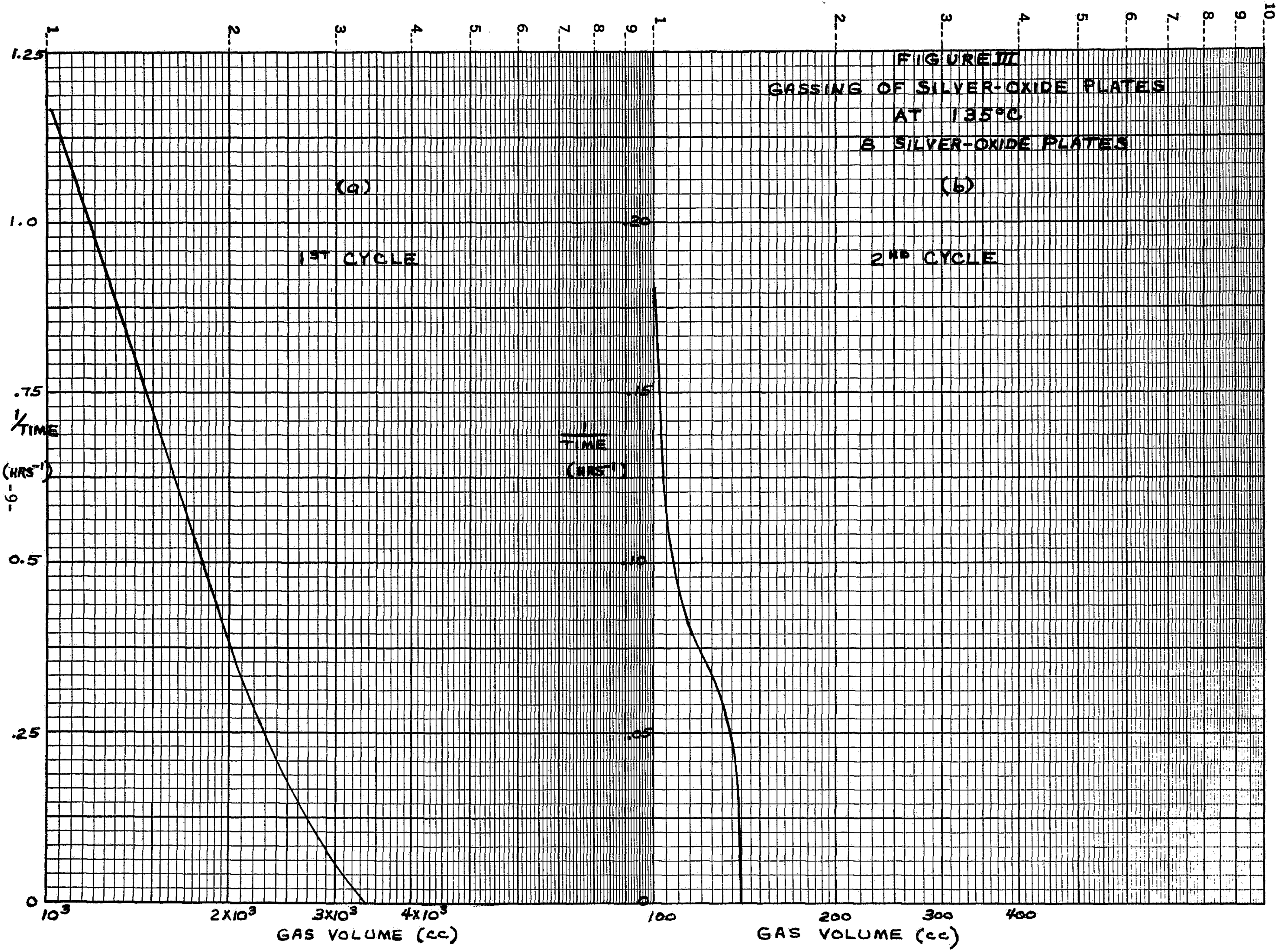


FIGURE III
GASSING OF SILVER-OXIDE PLATES
AT 135°C
8 SILVER-OXIDE PLATES
(a)
1ST CYCLE
(b)
2ND CYCLE
1/TIME (HRS⁻¹)
1/TIME (HRS⁻¹)
1.25
1.0
.75
0.5
.25
0
.20
.15
.10
.05
0
10³
2X10³
3X10³
4X10³
GAS VOLUME (cc)
100
200
300
400
GAS VOLUME (cc)

TABLE IV

SILVER OXIDE PLATES IN VACUUM

FOR 72 HOURS

AT 85°C

Plate No.	Original Weight	Final Weight	% Weight Loss	Length		% Increase Length	Width		% Increase Width	Thickness		% Increase Thickness
				Original	Final		Original	Final		Original	Final	
220	9.10	8.891	2.3	2.00	2.093	4.65	1.625	1.718	5.72	.026	.029	11.5
167	9.45	9.169	2.97	2.00	2.093	4.65	1.625	1.734	6.7	.031	.034	9.7

2.1 Silver Oxide Electrode (Continued)

2409 cotton separation material, and electroformed zinc electrodes in the same chamber. As a result of the test, it may be concluded that neither the released solvent nor the combination of the vacuum and the 85°C temperature had any ill effects on sterilized plates.

2.2 Zinc Electrodes

In order to determine the effects of heat sterilization on the electroformed zinc plates, a study was made using plates representing various weights and densities. All plates tested were die cut to dimensions of 2.00 inches high and 1.62 inches wide. After environmental testing each plate was discharged in cells consisting of two positive and one negative plates. The separation used was a single layer of 2409 cotton as manufactured by Kendall Mills. Capacity of each negative plate was determined as the discharge time to 1.00 volts at a 4.0 ampere rate.

The plates were divided into two groups. One of the groups was subjected to 135°C for 128 hours. Sterilization had no effect on the physical dimensions of the plates.

The sterilized and unsterilized plates were built into cells and discharged. The data are tabulated in Table V. No changes in cell voltages were effected by the sterilization. A comparison of the capacities shows an average capacity loss of 18% due to heat sterilization.

As a complementary study to that of direct heat sterilization, two plates were heat sterilized, subjected to a combination of reduced pressure with a temperature of 85°C for 72 hours and then sterilized again at 135°C for 138 hours, while in the presence of silver plates, 2409 cotton separation and polysulfone pieces joined with methylene chloride. Since the plates

TABLE V

EFFECTS OF STERILIZATION

On

ELECTROFORMED ZINC PLATES

Plate No.	Original Weight (gms)	Original Thickness (In.)	Original Density (gms/In^3)	Plateau Voltage (Volts)	Open Circuit Voltage (Volts)	Capacity (Amp-Min)	Remarks
208	4.11	.030	31.33	1.38	1.83	76.	Sterilized
205	4.14	.031	30.65	1.40	1.83	76.	Sterilized
376	4.15	.032	29.69	1.36	1.85	76.	Sterilized
242	4.21	.029	33.45	1.38	1.85	69.	Sterilized
203	4.22	.033	29.39	1.41	1.86	88.	Sterilized
134	4.40	.030	34.33	1.39	1.85	84.	Sterilized
19	4.40	.031	33.23	1.38	1.85	88.	Sterilized
145	4.40	.029	35.52	1.42	1.85	96.	Sterilized
251	4.40	.033	31.21	1.37	1.84	92.	Sterilized
202	4.40	.032	32.19	1.38	1.86	76.	Sterilized
44	4.66	.031	35.81	1.38	1.85	88.	Sterilized
143	4.66	.029	38.28	1.39	1.85	80.	Sterilized
313	4.66	.032	34.69	1.38	1.84	79.	Sterilized
233	4.67	.033	33.64	1.37	1.84	96.	Sterilized
264	4.99	.033	36.67	1.36	1.84	88.	Sterilized
175	5.00	.031	39.03	1.41	1.85	96.	Sterilized
59	5.04	.034	35.88	1.39	1.85	96.	Sterilized
191	5.34	.035	37.43	1.39	1.85	96.	Sterilized
77	4.89	.034	27.17	1.42	1.85	114.	Unsterilized
102	4.73	.031	28.84	1.39	1.84	94.	Unsterilized
115	4.40	.030	27.76	1.42	1.84	100.	Unsterilized
132	4.89	.030	30.85	1.40	1.84	108.	Unsterilized
192	4.73	.034	26.28	1.41	1.85	112.	Unsterilized
254	4.23	.029	27.65	1.42	1.85	92.	Unsterilized
285	4.40	.032	26.04	1.42	1.85	107.	Unsterilized
306	4.23	.032	25.03	1.42	1.85	108.	Unsterilized

2.2 Zinc Electrode (Continued)

will be in the battery cell case when the manifold is affixed, the effects of the environment and released solvent on the plates may be determined from this test. No change occurred dimensionally during the thermal-vacuum portion of the testing. The plates experienced a gain in weight during the sterilization cycles, but remained stable during the thermal-vacuum test. These plates shall be discharged and reported during the next quarter.

2.3 Separation

Since longer wet stands may require a separator more impervious to silver and zinc ions, a study of the effects of heat sterilization on 193 Pudo cellophane as manufactured by E. I. du Pont de Nemours, Inc., was made. Samples of the material were cut to a size of 2.00 inches by 5.00 inches. The samples were sterilized at 135°C for 128 hours while in polysulfone cell cases. The pieces were encased dry. None of the cell cases were sealed.

After sterilization the test articles were examined for physical deterioration. The samples experienced some shrinkage and minor discoloration. The results of this test are shown in Table VI.

2.4 Cell Case and Sealing

The primary effort during the past three months has been directed towards developing a technique for obtaining an effective seal with polysulfone. Various solvents were utilized. These included methylene chloride, ethylene dichloride, Hencosolve (H. A. Henderson Company), and a 5% solution of polysulfone in methylene chloride. All of these provided good seals with the polysulfone. However, a problem common to all solvents used was found during testing. At the 135°C sterilization temperature, solvent encapsulated in the polysulfone outgassed, clouding

TABLE VI

EFFECTS OF HEAT STERILIZATION

On

DU PONT 193 PUDO CELLOPHANE

Sample No.	Average Dimensional Change (%)			Remarks
	Length	Width	Thickness	
1	0.0	-0.3	-8.3	Slightly yellowed
2	-1.4	-0.9	-9.1	Slightly yellowed
3	0.0	-0.5	-15.4	Slightly yellowed

2.4 Cell Case and Sealing (Continued)

the areas which had been exposed to the solvent. Bonds made with the methylene chloride and ethylene dichloride solvents were cured at times up to 48 hours at room temperature with no improvement. Some of the specimens were subjected to vacuum for 48 hours. These clouded at the sterilization temperature. Various combinations of vacuum and temperature were then tried. It was determined that seals using methylene chloride could be reliably made with no apparent degradation at sterilization temperature if they were exposed to a reduced pressure of 300 microns or less in an ambient of 85°C for 72 hours.

After subjecting some right angle joints to the combination of temperature and vacuum and later to an ambient of 135°C for 138 hours, the specimens were broken. In each case, the break occurred well away from the weld, indicating a quality joint.

Dry sterilization of the polysulfone material has been conducted and reported earlier without any crazing or visible degradation. In order to determine the effects of potassium hydroxide on polysulfone, cell cases molded from 1700 grade polysulfone were filled with a 1.30 specific gravity solution of the electrolyte and subjected to 135°C sterilization. No degradation of the cases was found after sterilization.

Tests shall be conducted during the next period to determine the resistance of polysulfone to pressure. Electrical characteristics of cells sealed in polysulfone shall also be determined.

2.5 Electrolyte Solution

A study was made to determine the effects of various concentrations of electrolyte on the voltage and capacity characteristics of silver oxide-zinc cells. The tests involved combinations of unsterilized cells with unsterilized electrolyte, unsterilized cells with sterilized electrolyte, and sterilized cells with sterilized electrolyte. The cells consisted of one positive and two negative plates cut 2.00 inches by 1.62 inches. They were separated by a single layer of 2409 cotton as manufactured by Kendall Mills. Each cell was discharged to an end voltage of 1.00 volts at a rate of 4.0 amperes. The results are shown in Table VII.

In analyzing the results statistically, the capacity of the cells was found to be independent of the electrolyte concentration or sterilization status. With more than 99% of the variance explained, the capacity was found to be dependent on the sterilization of the cell and the original weights of the positive and negative plates. The no load voltage was affected by the electrolyte sterilization, while the plateau voltage was found to be dependent on the specific gravity of the potassium hydroxide.

2.6 Electrolyte Solution and Reservoir

During the past quarter the AN583AF propellant manufactured by Aerojet General was studied. The tests were made using gas generators containing 2.00 grams of propellant and two Atlas Chemical Industries IGN 17 ignitors. This initiator has a 0.5 ampere no-fire rating with a 2.25 ampere sure-fire. The bridgewire resistance is 0.44 ohms. The generators were sterilized and conditioned at various temperatures before performance testing. Performance testing was conducted in the fixture depicted in Figure IV. Pre-conditioning of the generators was done according to Table VIII. Results are shown in Table IX.

TABLE VII

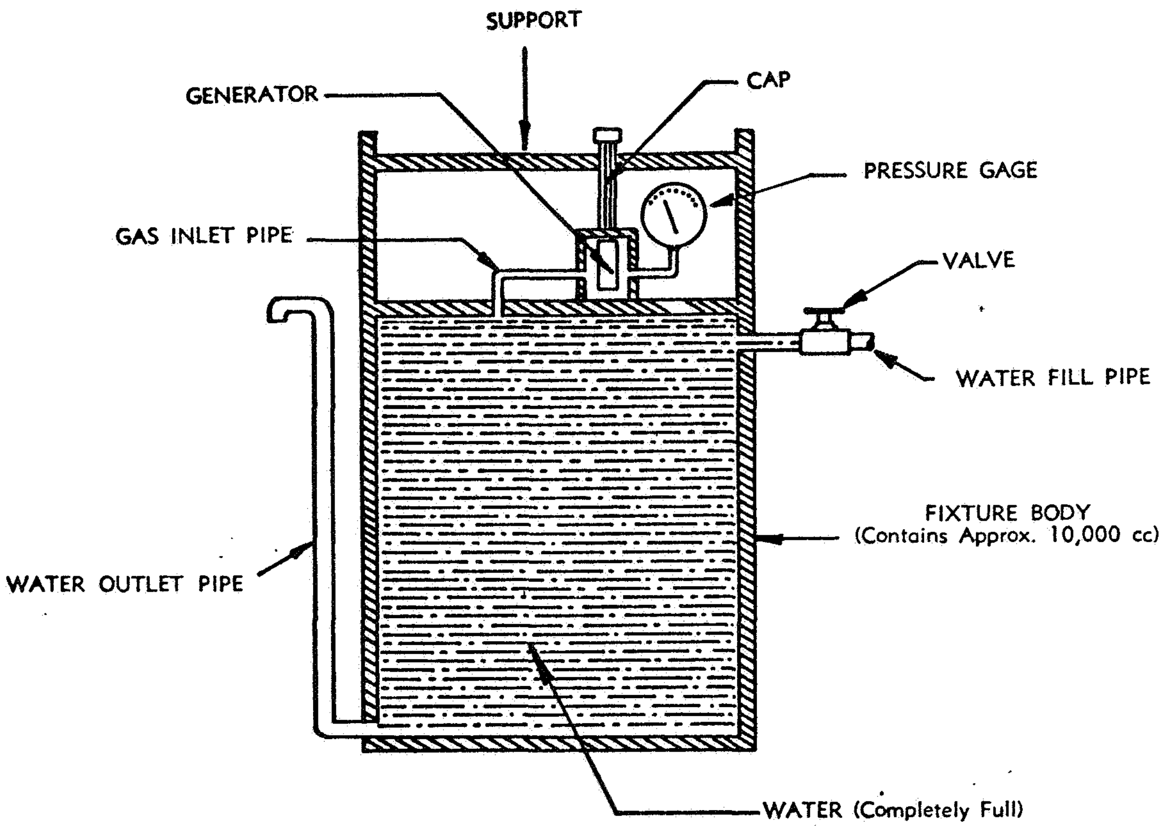
EFFECTS OF STERILIZED ELECTROLYTE

ON VOLTAGE AND CAPACITY

Cell		Electrolyte		Plate Wts.(Gms)		Voltage		Capacity
No.	Sterilized	Sp.Gr.	Sterilized	Positive	Negative	Plateau	Open Circuit	(Amp.Min.)
1	No	1.30	Yes	8.39	4.45 4.42	1.40	1.68	172
2	No	1.35	Yes	8.20	4.37 4.41	1.38	1.85	160
3	No	1.40	Yes	8.83	4.45 4.42	1.37	1.85	182
4	No	1.45	Yes	8.20	4.38 4.19	1.36	1.84	164
5	No	1.30	Yes	9.00	4.18 4.43	1.39	1.84	184
6	No	1.35	Yes	8.86	4.65 4.24	1.37	1.84	172
7	No	1.40	Yes	8.65	4.14 4.22	1.38	1.84	182
8	No	1.45	Yes	8.65	4.30 4.37	1.36	1.85	176
9	No	1.30	No	8.00	4.85 4.39	1.38	1.86	152
10	No	1.35	No	8.20	4.41 4.32	1.39	1.85	164
11	No	1.40	No	7.82	4.25 4.58	1.37	1.85	154
12	No	1.45	No	8.40	4.63 4.60	1.36	1.85	166
13	No	1.30	No	8.83	4.65 4.80	1.38	1.87	168
14	No	1.35	No	8.10	4.57 4.82	1.38	1.87	148
15	No	1.40	No	9.05	4.58 4.58	1.37	1.85	186
16	No	1.45	No	8.48	4.44 4.27	1.34	1.85	164
17	Yes	1.30	Yes	7.74	4.32 4.32	1.38	1.61	84
18	Yes	1.35	Yes	8.32	4.43 4.41	1.39	1.62	86
19	Yes	1.40	Yes	8.95	4.46 4.51	1.38	1.62	96
20	Yes	1.45	Yes	7.90	4.60 4.59	1.34	1.64	84
21	Yes	1.30	Yes	8.96	4.93 4.31	1.40	1.61	96
22	Yes	1.35	Yes	8.85	4.56 4.26	1.39	1.63	94
23	Yes	1.40	Yes	8.65	4.52 4.34	1.36	1.63	92
24	Yes	1.45	Yes	9.00	4.78 4.35	1.37	1.63	96

APPLICATION	
NEXT ASSY	USED ON

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



Typical Water Displacement Test Fixture.

FIGURE IV

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONS ± ANGLES ± 3 PLACE DECIMALS ±.010 2 PLACE DECIMALS ±.03	CONTRACT NO. DATE ______		EAGLE PICHER INDUSTRIES, INC. COUPLES DEPARTMENT JOPLIN, MISSOURI
	PREPARED		
	CHECKED		
	ENGINEER		
			SIZE A · CODE IDENT NO. 81855 · DRAWING NO.
			SCALE · SHEET

TABLE VIII

GAS GENERATOR TESTS

Unit	Stabilization Time (°C)	History
1	R.T.	None
2	R.T.	None
3	R.T.	None
4	0	Sterilized
5	0	Sterilized
6	0	Sterilized
7	51.5	Sterilized
8	51.5	Sterilized
9	51.5	Sterilized
10	60	Sterilized, Stabilized @ 60°C for 14 days
11	60	Sterilized, Stabilized @ 60°C for 14 days
12	60	Sterilized, Stabilized @ 60°C for 14 days
13	74	Sterilized
14	74	Sterilized
15	74	Sterilized

TABLE IX

AN583AF PROPELLANT PERFORMANCE

At

VARIOUS TEMPERATURES

Gas Generator Number	Volumetric Output (cc)	Displacement Time (Sec.)	Peak Pressure (psig)	Time to Peak (Sec.)	Remarks
1	*	*	*	*	Stabilized @ 60°F, Sterilized
2	550**	4	**	**	Stabilized @ 60°F, Sterilized
3	1300	5	15	4.4	Stabilized @ 60°F, Sterilized
4	1220	6	5	4.9	Stabilized @ 0°F, Sterilized
5	500**	4	**	**	Stabilized @ 0°F, Sterilized
6	1400	5	11	3.37	Stabilized @ 0°F, Sterilized
7	1280	6	3***	5.35	Stabilized @ 115°F, Sterilized
8	*	*	*	*	Stabilized @ 115°F, Sterilized
9	1425	4	14	2.55	Stabilized @ 115°F, Sterilized
10	800**	5	5	3.35	Stabilized @ 140°F, Sterilized
11	1265	5	12	3.1	Stabilized @ 140°F, Sterilized
12	1320	5	13	3.7	Stabilized @ 140°F, Had one bridgewire open, Sterilized
13	1600	5	****	****	Stabilized @ R.T., No Sterilization
14	1400	7	17	5.2	Stabilized @ R.T., No Sterilization
15	1380	5	15	2.4	Stabilized @ R.T., No Sterilization

* Bridgewires in ignitors were open circuit

** Propellant did not completely burn

*** Orifice in fire tower restricted

**** Data lost due to loose connection at power supply

2.6 Electrolyte Solution and Reservoir (Continued)

As noted in Table IX, several malfunctions occurred during the testing. The most prevalent was the failure of some of the generators to fire on application of current. A tear-down of the failed units revealed that the ignition spot surrounding the bridgewire had degraded during sterilization and had not ignited. However, the bridgewire had burned open. According to the manufacturer, the ignition mix is basically a nitrocellulose which is not reliable at the storage temperatures involved.

Another apparent problem was that of the propellant failing to burn completely. Since a pressure must be maintained on the propellant to prevent self-extinguishing, the design of the generator was probably at fault. By orificing the exhaust, a pressure sufficient to maintain combustion should be attained. The propellant exhibited a relatively uniform volumetric displacement. Compared to similar gas generators using N-5 propellant, the pressure rise to peak is slower with the AN583AF. If the burning rate were increased by increasing the pressure inside the generator, the time to peak pressure should be more comparable to that of N-5. The pressure attained, however, might be greater. Further testing of the propellant shall be done along with the substitution of initiators capable of the heat sterilization.

3.0 CONCLUSIONS

As a result of the studies made to date, several conclusions may be drawn. The positive (silver-oxide) plates have been shown to suffer a loss in capacity of approximately 40% due to sterilization. If the plates are subjected to at least 60 hours at 135°C and then sterilized, the weight losses and physical growths in the battery can be minimized. The resultant loss in capacity due to the pre-conditioning and sterilization cycles is approximately 42%.

3.0 CONCLUSIONS (Continued)

Based on a plate weight of 8.0 grams and an oxygen pickup of 12%, the amount of gas released during a 135°C sterilization cycle would be 400 cc per plate. During a second sterilization approximately 17 cc per plate would be released.

The silver oxide plates were unaffected by the reduced pressure and elevated temperature when previously sterilized. A 2.5% weight loss and dimensional growth similar to those of sterilized plates occur during the thermal vacuum storage when the plates have not been previously sterilized. The solvent released apparently has no effect on the silver or zinc plates.

Zinc plates were found to experience a capacity loss of 18% due to sterilization at 135°C for 120 hours. The dimensions of the plates were unaffected.

Separator 193 Pudo manufactured by Du Pont was found to be capable of 135°C dry sterilization. When sterilized, the material experienced minor shrinkage and slight discoloration.

An effective means of sealing polysulfone using methylene chloride has been developed. In order to pass the sterilization cycle, a 72 hour storage of the part in an atmosphere of 85°C and a 300 micron pressure or less must be used.

Polysulfone has been shown capable of dry sterilization. It has also been shown resistant to boiling potassium hydroxide.

In the analysis of various electrolyte solutions, the following conclusions may be made. Neither the concentration nor sterilization of the electrolyte affect the capacity of the silver oxide-zinc cell. The no load or open circuit voltage was reduced by sterilization of the electrolyte while the plateau voltage is reduced as the specific gravity is increased.

3.0 CONCLUSIONS (Continued)

The AN583AF propellant exhibits a relatively uniform water displacement. Compared to the N-5 propellant presently used in remotely activated systems, the pressure time relationship is slow. It is felt that a generator design which maintains a slightly higher pressure on the burning propellant would result in a more rapid rise in pressure.

4.0 RECOMMENDATIONS

From data accumulated so far the silver oxide plates should be stored at 135°C for at least 60 hours prior to cutting the plates to size. This would eliminate problems of plate growth and excessive gas buildup.

Polysulfone apparently has the properties desirous of a cell case material. With the seals attainable using methylene chloride, the material is readily adaptable to present techniques in cell case fabrication.

5.0 NEW TECHNOLOGY

No new technology was developed during the third quarter of the contract.